Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on
Preliminary Geotechnical Investigation

Proposed Rural Land Sharing Communities
Kyogle Road, Kunghur

Prepared for
NCV Enterprises Pty Ltd

Project 90579.00
March 2019

Douglas Partners
Geotechnics / Environment / Groundwater

Document History

Document details

Project No.	90579.00	Document No.	R.001.doc
Document title	Report on Preliminary Geotechnical Investigation Proposed Rural Land Sharing Communities		
Site address	Kyogle Road, Kunghur		
Report prepared for	NCV Enterprises Pty Ltd		
File name	90579.00.R.001.doc		

Document status and review

Status	Prepared by	Reviewed by	Date issued
Revision 0	Gary Samuels	Chris Bell	11 March 20192019

Distribution of copies

Status	Electronic	Paper	Issued to
Revision 0	1	0	NCV Enterprises Pty Ltd

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author		11 March 2019
Reviewer		11 March 2019

bsi. ISO 9001 Quality Management
FS 604853

Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
Unit 2, 3 Distribution Avenue
Molendinar QLD 4214
Phone (07) 5568 8900

Table of Contents

Page

1. Introduction....1
2. Site Description....2
3. Regional Geology....3
4. Field Work Methods....4
5. Field Work Results....4
   - 5.1 Walkover Survey....4
   - 5.2 Subsurface Conditions....5
6. Proposed Development....7
7. Preliminary Comments....7
   - 7.1 Excavatability....7
   - 7.2 Batter Slopes....7
   - 7.3 Re-Use of Cut Materials and Workability....8
   - 7.4 Subgrade Preparation and Fill Placement or Recompaction....9
   - 7.5 Site Classification....10
   - 7.6 Foundations....11
   - 7.7 Landslip Hazard Risk Assessment....13
     - 7.7.1 Preliminary Comment....13
     - 7.7.2 Drainage....15
   - **7.8 Constant Head Permeability Test Result**....15
8. References....16
9. Limitations....16

Appendix A: About This Report
Sampling Methods
Soil and Rock Description
Symbols and Abbreviations

Appendix B: Drawing 1 – Test Location Plan

Appendix C: Borehole Logs (Bores 1 to 17)

Appendix D: CSIRO Publication

Appendix E: Australian Geoguides LR8

Report on Preliminary Geotechnical Investigation
Proposed Rural Land Sharing Communities
Kyogle Road, Kunghur

1. Introduction

This report presents the results of a preliminary geotechnical investigation undertaken for proposed concept rural land sharing communities to be located at Kyogle Road, Kunghur. The investigation was carried out at the request of Planit Consulting Pty Ltd (project engineers) on behalf of NCV Enterprises Pty Ltd (NCV) Pty Ltd (project developer) in accordance with Douglas Partners Pty Ltd (DP) fee proposal GLD180344 dated 24 November 2018, and the acceptance received from Ms Cherie Stokes representing (NCV) on 18 December 2018.

It is understood that potentially 459 rural land share dwellings may be constructed along the ridgelines and level areas of the site. Details on earthwork levels and structural loads were not known at the time of the preparation of this report.

The aim of the assessment was to carry out a preliminary geotechnical investigation and provide preliminary comments on the following:

- subsurface conditions including groundwater, if encountered;
- site classification in accordance with AS2870-2011 (Ref. 1);
- earthworks and site preparation including comments on topsoil stripping, excavatability, trafficability, compaction and re-use of site soils/rock;
- suitable foundation options, design pressures and settlements;
- temporary and permanent batter slopes;
- landslip risk assessment in accordance with the Australian Geomechanics Society (AGS);
- comments on good hillside construction techniques including comments on adequate restrictions on any earthworks including excavation/cutting and filling; and
- indicative permeability of predominant soil types.

The preliminary investigation comprised the drilling of 17 bores across the proposed development site, a landslip hazard risk assessment and six constant head permeability tests. Details of the field work are presented in this report, together with comments and recommendations on the items listed above. The landslip hazard risk assessment was restricted to the proposed roads, dwelling locations and nearby surrounding land and as such, only represents these areas and not the entire site.

This report must be read in conjunction with all of the notes in Appendix A and should be kept in its entirety without separation of individual pages or sections.

2. Site Description

The site is located beyond the north western side of Kyogle Road, Kunghur and is bounded by bushland to the west, north and south and Kyogle Road to the south east as shown in Figure 1.

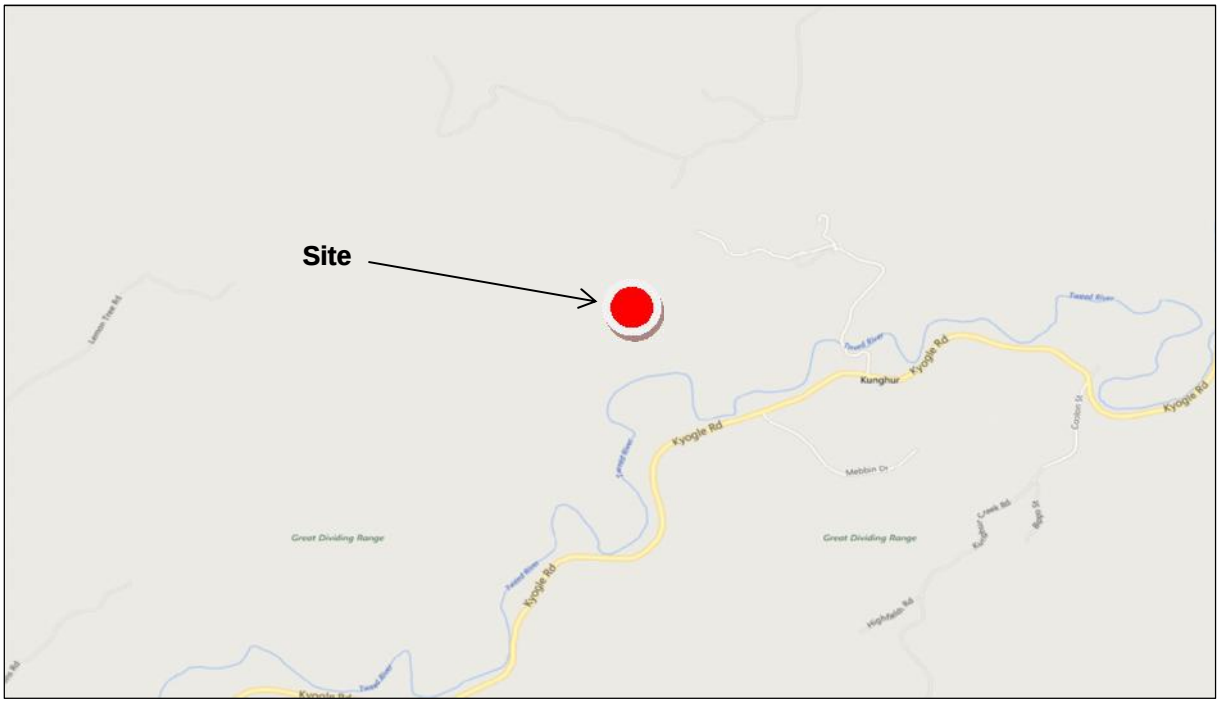


Figure 1: Site locality.

The site was predominantly mountainous and comprised thick bushland with several minor areas of open grass and dirt access tracks throughout. The site sloped in multiple directions away from ridgelines and had numerous gullies throughout. Several earth dams and small sheds/shade structures were also observed within the development site.

Figures 2 and 3 indicate typical site conditions encountered during the investigation.

Figure 2: Looking north from near Bore 9.

Figure 3: Looking west from near Bore 4.

3. Regional Geology

Based on the Geological Survey of New South Wales 250,000 series, Statewide Geodatabase, the site is underlain by the early Jurassic to late Triassic aged Woogaroo Subgroup, typically comprising *'sandstone, siltstone, claystone, conglomerate and coal'.* Residual soils are expected to overlay the rock.

The field work encountered residual clays over sandstone or siltstone, the latter two of which are consistent with part of the rocks described in the published geology.

4. Field Work Methods

The field work was undertaken between the 14 and 16 January 2019, and included a walkover inspection of the site and adjacent surrounding area by a Senior Engineering Geologist, and the drilling of 17 bores (designated Bores 1 to 17).

The bores were drilled to refusal depths of between 1.0 m and 2.4 m or the target depth of 3 m using a Soil Christie drill rig employing 100 mm solid flight auger techniques fitted with a Tungsten Carbide (TC) drill bit.

Strata identification was undertaken through observation of recovered auger cuttings. Disturbed samples were retrieved at each significant strata change in each bore. On completion of drilling, and after checking for groundwater inflow, the bores were backfilled with drill spoil.

Insitu dynamic cone penetrometer (DCP) tests were conducted beside each bore to 'effective' refusal depths of between 0.8 m and 2.2 m.

The test locations were positioned with reference to existing and proposed site features, and the locations were recorded using a hand held GPS accurate to within 5 m and are presented on the borehole logs. The approximate bore locations are indicated on Drawing 1 in Appendix B. Given the absence of site survey plans, surface levels were interpolated from Nearmap imagery dated 1 January 2005.

The field work and soil logging of the bores was carried out by a Senior Engineering Geologist from DP's Ballina office.

Constant head permeability test was carried out in accordance with AS/NZ 1547 2012 *'On site Domestic Waste Water Management'* (Ref 10) adjacent to Bores 2, 5, 7, 11, 13 and 16.

5. Field Work Results

5.1 Walkover Survey

This component of the investigation was limited to the areas where roads and dwellings are proposed, which were predominantly along existing ridgelines or level areas of the site, and was carried out to assess the site for the following:

- slope angle;
- vegetation;
- tension cracking;
- seepage;
- soil creep;
- previous slips;
- geological features; and
- drainage issues.

Generally, the slope angles of the site varied from <5º to 30º across proposed development areas.

Large portions of the site comprised thick undergrowth and bushland making it inaccessible in part. However, where accessible, no landslip movement, seepage, soil creep, tension cracking or seepage was observed during the site walkover.

5.2 Subsurface Conditions

Details of subsurface conditions encountered in the bores are given in the borehole logs presented in Appendix C. These must be read in conjunction with the attached general notes giving details of the descriptive terms and classification methods used in their preparation.

In summary, the subsurface conditions encountered at the test locations comprised a veneer of medium dense or denser silty/clayey sand overlaid stiff or stronger residual clays then weathered siltstone/sandstone.

A summary of the subsurface conditions encountered at each test location are shown in Table 1.

Table 1: Summary of Subsurface Conditions

Bore	Strata/Depth Range (m)[(i)]			
	Silty/Clayey Sand (medium dense or denser)	Clay (stiff or stronger)	Completely weathered siltstone/sandstone (encountered as hard silty/sandy clay)	Siltstone (very low strength or stronger)
1	0.0 – 0.5[(ii)]	0.5 – 1.1	1.1 – 1.9	1.9 – 2.4[(iii)]
2	0.0 – 0.3	0.3 – 0.9	-	0.9 – 1.0[(iii)]
3	0.0 - 0.4[(ii)]	0.4 – 1.8	1.8 – 3.0	-
4	0.0 – 0.1[(ii)]	0.1 - 3.0	-	-
5	0.0 – 0.1	0.1 – 2.7	2.7 – 3.0	-
6	0.0 - 0.2	0.2 – 1.2	1.2 – 1.7	1.7 – 1.8[(iii)]
7	0.0 – 0.1	0.1 – 3.0	-	-
8	0.0 – 0.1	0.1 – 3.0	-	-
9	0.0 – 0.2	0.2 – 1.5	1.5 – 3.0	-
10	0.0 – 0.1	0.1 – 3.0	-	-
11	0.0 – 0.1	0.1 – 3.0	-	-
12	0.0 – 0.3	0.3 – 3.0	-	-
13	0.0 – 0.1	0.1 – 3.0	-	-
14	-	0.0 – 0.9[(iv)]	0.9 – 3.0	-
15	-	0.0 – 3.0	-	-
16	0.0 – 0.1	0.1 – 3.0	-	-
17	0.0 – 0.1	0.1 – 2.8	2.8 – 3.0	-

Notes: (i) All depths measured from surface level at the time of the investigation
(ii) Root zone to 0.1m.
(iii) TC Bit refusal in very low to low strength rock.
(iv) Tree Roots to 0.7m.

No free groundwater was encountered during the investigation. It should be noted that groundwater depths and ground moisture conditions are affected by climatic conditions and soil permeability, and therefore may vary with time.

6. Proposed Development

It is understood that the site is to be subdivided into potentially 459 rural land share dwellings. Details on earthworks levels and structural loads were not known at the time of the investigation.

7. Preliminary Comments

7.1 Excavatability

Based on the conditions encountered within the bores, it is estimated that the excavation of materials above 'TC' bit refusal depths could readily be undertaken by small to medium sized excavation plant such as backhoes and 8 to 15 tonne hydraulic excavators for trench excavations, and D7/D8 dozers for bulk earthworks, with scrapers and push-loading and or ripping to assist production rates in the harder areas of these materials. Below 'TC' bit refusal depths, comments on the type of equipment that may be suitable for excavation cannot accurately be made due to the limit of the investigation.

It should be recognised that the above excavatability estimates are based on materials encountered at the test locations only and that conditions may prove more difficult (or easier) for excavatability beyond these test locations.

7.2 Batter Slopes

Unsurcharged batter slopes cut up to 3 m vertical height within the subsurface profiles encountered in the bores may be designed for short and long term conditions as presented in Table 2.

Table 2: Recommended Batter Slope Angles

Material Type	Short Term	Long Term
Sand – medium dense or denser	2H:1V	3H:1V
Residual Clay - stiff or stronger/Controlled Fill(1)/Completely weathered rock	1H:1V	2H:1V(2)
Sandstone/Siltstone (very low strength or stronger)	1H:1V	1H:1V(2)

Notes (1) Assuming controlled filling is placed under Level 1 inspection and testing by DP in accordance with the recommendations of this report.
(2) Long term slopes in engineered filling, stiff (or stronger) clays or completely weathered rock would require surface protection to reduce the risk of erosion potential. Steeper slopes may be possible, subject to detailed stability analysis and/or site inspection during excavation.

If access for maintenance of slopes or vegetation is required (eg mowing), slopes may need to be flattened to 3H:1V or less. All fill batters should be over filled, compacted and cut back at the above batter slopes.

The above temporary batter slopes are suggested with respect to slope stability only, and do not allow for lateral stress relaxation which may result in movement of nearby in-ground services or shallow footings. If such services or footings are settlement-sensitive, and are located near the crest of the cut face, then the excavation may have to be positively supported.

It is recommended that all cut and fill batters incorporate drainage at the crest and toe, and be covered with topsoil and vegetation to provide long term erosion protection.

Additional assessment by DP is recommended once earthwork levels are available to confirm the factor of safety for global stability of proposed cut/filling batters or retaining structures.

7.3 Re-Use of Cut Materials and Workability

Based on the results of the bores, it is expected that suitable structural filling won from excavation will predominantly comprise residual clays or weathered siltstone/sandstone. The very low strength siltstone/sandstone could be expected to break down to form a gravelly sandy clay to clayey sandy gravel upon compaction. Rock below 'TC' bit refusal depths may be more difficult to break down and may require large plant such as 20t or heavier compaction plant or possibly crushing and screening.

It is expected that the excavated materials, with the exception of the organic bearing strata, could all be reused as structural filling. Such re-use is contingent upon acceptance of the estimated reactive soil movements (refer Section 7.5) and on the filling being free of any unsuitable materials, particle size distribution being controlled along with moisture content, and upon minimum placement and compaction requirements being met, as indicated in Section 7.4.

Care should be taken not to over-wet the clayey soils which can lead to problems associated with trafficability and workability. Clay soils should not be over-compacted (i.e. not more than 102% Standard) or dry of optimum, as this can lead to future swelling and softening under changes to moisture content or inundation from water. Clay subgrades should be promptly overlaid with nominal 150 mm of select granular filling (minimum CBR 15%) to reduce potential wetting and trafficability problems.

Where clay is proposed to be re-used as filling platforms beneath any structure or pavement, it is recommended that cohesive material be placed at depth and any crushed weathered rock won from excavations at site, or imported well graded granular material be placed close to founding level. This will reduce the effects of seasonal moisture change and foundation soil reactivity, and will improve surface trafficability.

The medium to high plasticity clay materials and completely weathered rock may be untrafficable to tyred vehicles during and after periods of rainfall or other increases in subgrade moisture content, and hence, the use of tracked plant may be preferable. Soils which become wet will need to be allowed to dry out or be replaced.

7.4 Subgrade Preparation and Fill Placement or Recompaction

Where upper level footings are to be used and on-ground slabs are adopted, it is recommended that the following site preparation be carried out for structural foundations and pavement subgrades:

- Removal of any deleterious, 'uncontrolled' filling, soft soils, wet or highly compressible material, or material rich in organics or root matter to a competent natural strata. It is noted that 'uncontrolled' filling and soft soils were not encountered in the bores, and that allowance should be made for rootlets and organics to potentially exist in vegetated areas up to about 0.2 m depth. However at Bore 14 tree roots up to 0.7 m depth was encountered and therefore, deeper or shallower areas of stripping may be locally required;
- Test roll the subgrade beneath any proposed filling, structure or pavement in order to detect the presence of any further soft or loose zones, which should be ripped, dried and recompacted, or excavated and replaced with compacted select filling as appropriate;
- Undertake test rolling should using a smooth drum roller with a minimum static weight of 12 tonne. The tyned natural foundation soil should be compacted to a minimum density index of 70% (sands) or minimum dry density ratio of 95% Standard (clays);
- Bench competent natural slopes which exceed 1V:8H prior to any filling placement, where benched heights do not exceed 0.5 m and be graded positively away from the slope;
- Assess moisture contents of the underlying clays, which should be adjusted so they are within ±2% of OMC, where OMC is the optimum moisture content at Standard compaction. Approved filling should then be placed in layers not exceeding 300 mm loose thickness, with each layer compacted to a minimum dry density ratio of 95% Standard (clay) or 70% Density Index (sand). Within 0.5 m of the subgrade of any heavy duty pavement for trucks, the fill should be compacted to a minimum dry density ratio of 100% Standard. Where filling is clayey, moisture content within the filling should be maintained within ±2% of OMC during and after compaction;
- Limit over-compaction of clays (i.e. minimum dry density ratio of >102% Standard) which may swell significantly and lose strength if they are wetted after compaction, potentially changing the site classification and reducing subgrade strengths assumed in design, and therefore should be avoided;
- Seal or cover as soon as practicable any compacted clay foundation soil at or close to footing formation level to reduce the opportunity for occurrence of desiccation and cracking; and
- Undertake 'Level 1' inspection and testing, by DP, as detailed in AS 3798–2007 (Ref. 3), where new filling is required to achieve design levels under buildings or pavements should be.

The above procedures will require geotechnical inspection and testing services, by DP, to be employed during construction.

It is also noted that new filling will undergo settlement due to self-weight. As a guide, well compacted clayey filling is expected to experience settlements of about 1% of fill thickness over a twenty year period.

7.5 Site Classification

Site classification of foundation soil reactivity in accordance with AS 2870-2011 (Ref. 1) strictly only applies to residential houses as is anticipated at this site. Such classification provides an indication of the propensity of the ground surface to move with seasonal variation in moisture, and has been used (along with general climatic zoning (Ref 2) and general experience) to assess the potential depth of seasonal cracking.

Based on previous experience in the regional area, the natural clays or completely weathered rock are expected to have characteristic surface movement (y_s) values between 20 mm and 40 mm, consistent with a 'Class M' (moderately reactive) classification at the lower range of y_s values and up to 40 mm to 60 mm consistent with a 'Class H1' (highly reactive) classification at the upper range of y_s values.

Where controlled filling is to be placed to create level building platforms, the individual lot classifications will be a function of the depth and reactivity of the filling used to create the building platform which is unknown at this time, and larger movements with a more severe classification could possibly occur. The above indicative range of y_s values are intended as a guide and individual lot classifications will be required following bulk earthworks at the site.

No assessment of the effect of soil moisture change by trees has been made in the above y_s estimates (either with respect to the removal of established trees prior to development of building pads, or the proximity of established or new trees to proposed buildings). Reference to the requirements in AS 2870-2011 should be made by the building designer in this regard. It should be further noted that the presence or removal of trees can result in additional surface movement, due to tree-induced suction changes and tree-induced centre heave. Such tree-induced movement is not included in the characteristic surface movement estimate provided above.

If 'abnormal' soil moisture conditions are experienced at the site, the site would be classified as 'Class P' (problem site) which would require more extensive foundation works or could result in adverse foundation performance. Abnormal soil moisture conditions are defined in AS2870 (Clause 1.3.3) and, in summary, comprise:

- Recent removal of buildings or structures likely to have affected soil moisture conditions;
- Unusual moisture caused by drains, channels, ponds, dams or tanks;
- Recent removal of large trees (possible if trees are removed);
- Growth of trees too close to a structure (possible if trees are left in pace);
- Excessive or irregular watering of gardens adjacent to the structure;
- Lack of maintenance of site drainage; and
- Failure to repair plumbing leaks.

The above results indicate good practice in design, construction and management of the site will be required to accommodate the potential site movements. In particular, good surface and subsurface drainage will be required, along with limits on landscaping and adequate moisture preparation. CSIRO Guidelines (BTF18) (Ref. 4) on site management for homeowners is also attached to this report as well as guildelines for 'good building practice' on sloping sites, as shown in Appendix E, and provides useful advice for this site.

7.6 Foundations

7.6.1 General

High level pad/strip footings or short bored pier foundations are expected to be suitable for the support of the proposed structures and can be designed using the allowable parameters given in Tables 3 and 4.

Where limit state methods are used to design the foundations, the ultimate geotechnical strength ($R_{d,ug}$) can be calculated by multiplying the allowable parameters (given in Tables 3 and 4) by the adopted safety factor of 2.5, and then multiplied by a suitable geotechnical strength reduction factor ($\leftarrow_g$) to obtain the design geotechnical strength ($R_{d,g}$).

A nominal $\leftarrow_g$ value of 0.5 is recommended for high level footings.

The Piling Code AS 2159–2009 (Ref. 6) requires a $\leftarrow_g$ value of 0.45 to 0.65 where there is no testing of pile capacity, rising to 0.65 to 0.85 where a significant number of piles are tested after installation.

It is essential that foundation excavations (where applicable) be inspected by experienced geotechnical personnel to ensure the design parameters adopted are suitable for the ground conditions and to ensure that there is no soft or loose material remaining at the base of the excavations or smear on the side walls. Ground conditions can vary, and adequate provision should be made throughout the project to vary foundations to suit differing ground conditions.

7.6.2 High Level Footings

High level strip and pad footings to a maximum width of 0.5 m and 2 m respectively, may be sized using the allowable values indicated in Table 3. Structural footings and slab design should consider the final lot classification following bulk earthworks and include applicable stiffening. Foundations bearing on differing strata will experience differential settlements which may require extending foundations to uniform bearing strata.

Table 3: High Level Footing Design Bearing Pressures (Allowable)

Material Description	Maximum Allowable Bearing Pressure (kPa)
Sands – medium dense or dense	NR
Controlled Filling(i)/ Residual Clay – stiff or stronger	100
Completely weathered rock described as hard sandy/silty clay	400
Siltstone/Sandstone – very low strength or stronger	600

Notes (i) Assuming controlled filling is placed under Level 1 inspection and testing by DP in accordance with the recommendations of this report.

(ii) NR – Not Recommended.

For high level pad or strip footings founded in the materials as given in the above table, it is considered that settlements under such applied loading will be less than 1% to 2% of footing width.

7.6.3 Piled Foundations

Where high level foundations are not suitable, pile foundations such as bored piles are expected to be a suitable footing option. Bored piles with a length on dimeter ratio of four and founding a minimum of one pile diameter into rock can be preliminarily designed using the allowable values indicated below in Table 4. Pile capacities and suitable pile types should be confirmed by prospective piling contractors.

Table 4: Design Parameters (Allowable) for Bored Piles

Material Description	Allowable Shaft Adhesion* (kPa)	Allowable End Bearing (kPa)
Sands – medium dense or denser	NR	NR
Controlled Filling[(i)]	20	NR
Silty/sandy clay - stiff (or stronger)	20	225
Completely weathered rock	30	600
Siltstone/Sandstone – very low strength or stronger	60	1000

Notes (i) * Ignore upper 1.5 D of soil to allow for soil shrinkage and shaft load development where D is the diameter of the pile.

(ii) Assuming controlled filling is placed under Level 1 inspection and testing by DP in accordance with the recommendations of this report.

For bored pile foundations loaded as per the allowable bearing pressures in Table 4 above, it is considered that settlements under such applied loading will be less than 1% to 2% of the pile diameter.

It is recommended that the upper 0.9 m depth of soil be ignored in pile shaft adhesion calculations due to the effects of seasonal moisture variation and shaft load development effects.

Pile capacities and suitable pile types should be confirmed by prospective piling contractors based on their particular equipment.

Where limit state methods are used to design the piles, the ultimate geotechnical strength ($R_{d,ug}$) can be calculated by multiplying the allowable factors by the adopted safety factor of 2.5, and then by a suitable geotechnical strength reduction factor (Φ_g) to obtain the design geotechnical strength ($R_{d,g}$). After assessing the overall design average risk rating in accordance with the guidelines presented in AS2159–2009 (Ref. 5), a Φ_g value of 0.5 is suggested for the site.

It is essential that foundation excavations (where applicable) be inspected by experienced geotechnical personnel to ensure the design parameters adopted are suitable for the ground conditions and to ensure that there is no soft or loose material remaining at the base of the excavations or smear on the side walls.

Ground conditions can vary, and it is essential that adequate provision be made throughout the project to vary foundations to suit differing ground conditions.

7.7 Landslip Hazard Risk Assessment

7.7.1 Preliminary Comment

The landslip hazard risk assessment was restricted to the proposed roads and dwelling locations and nearby surrounding land.

Where access was achieved, physical evidence of previous landslip movement, seepage, soil creep, slumps or tension cracking was not observed during the site walkover. However, given the presence of thick vegetation, access was limited for the site walkover and as such, it is recommended that an additional inspection be carried out post clearing and grubbing to confirm the above initial findings.

An indicative quantitative and qualitative hazard rating has been calculated for the site considering existing *'worst case scenario'* site conditions encountered during the site walkover and field work, using published methods as per the Australian Geomechanics Society (AGS).

Table 5: Slope Instability Risk Assessment using AGS 'A Method of Zoning Landslip Hazard' (Ref 7).

Category	Description	Level of Risk	Factor
Slope Angle	Between 15º and 30º	Medium	0.8
Slope Shape	Planar	Low	0.9
Site Geology	Low grade sedimentary rock	Medium	1
Material Strength	Residual soils 1- 3 m deep	Medium	0.9
Concentration of surface water	Lower slope	High	1.5
Evidence of groundwater	None apparent	Low	0.7
Evidence of instability	No sign of instability	Low	0.5
Relative Frequency			**0.34**

The result of this assessment provided relative frequency value of 0.34 for existing site conditions which indicated the site has a 'low' and likelihood of instability in its present state (refer to Table 6).

Tables 6 and 7 below indicate typical implications with respect to the correlation between relative frequency and likelihood rating and the site 'risk' level.

Table 6: Correlation between Relative Frequency and Likelihood Rating

Relative Frequency	Likelihood Rating
<0.2	Very low
0.2-0.6	Low
0.6-2.0	Moderate
2.0-6.0	High
>6.0	Very High

Table 7: Risk Level Implications

Risk Level		Example Implications[1]
VH	Very High	Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to acceptable levels; may be too expensive and not practical.
H	High Risk	Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable levels.
L	Low Risk	Tolerable provided treatment plan is implemented to maintain or reduce risks. May be accepted. May require investigation and planning of treatment options.
VL	Very Low	Acceptable. Manage by normal slope maintenance procedures.

Notes: 1. The implications for a particular situation are to be determined by all parties to the risk assessment; these are only given as a general guide.
2. Judicious use of dual descriptors for Likelihood, Consequence and Risk to reflect the uncertainty of the estimate may be appropriate in some cases.

Parameters were determined and assigned, as shown in Table 8, for the AGS qualitative landslip assessment, as per AGS *'Landslide Task Force, Landslip Practice Note Working Group'* based on the requirement that all uncontrolled filling will be removed and replaced with engineered filling.

Table 8: Slope Instability Risk Assessment for Properties using AGS *'Landslide Task Force, Landslip Practice Note Working Group' (Ref 6 and 8)*

Hazard	Likelihood	Consequence to proposed Development	Risk to proposed Development
Creep of natural residual soils	Rare	Insignificant to major	Very low to low
Deep seated instability within the site	Barely Credible	Major to Catastrophic	Very low to low

Note i) Insignificant if buildings are piled into weathered rock; major if buildings are on high level footings.

The result of this assessment indicated a *'very low to low'* risk to the proposed development with regards to instability in its present state.

For both landslip risk methods, it can be concluded that a *'very low to low'* risk of instability could be expected for the proposed development.

The above analysis assumes that all the recommendations made in this will be adhered to, that DP will undertake all required additional detailed assessments, earthwork compaction control and inspections of cut/fill batter verification, as required, and that a suitable stormwater management plan will be designed, implemented and verified by a duly qualified hydraulics engineer.

7.7.2 Drainage

Adequate drainage and controlled removal of run-off from any sloping site is a crucial element of good hillside development practices. In this respect, it is recommended that any flows of water onto the slopes should be minimised, in order to reduce the potential for saturation, possible instability and scour.

All stormwater flows collected from the roofs of buildings, other impermeable areas, surface drains and retaining walls should be collected by a stormwater drainage system and discharged via pipes with flexible joints or lined channels to the street stormwater drainage system.

General guidelines for good building practices or sloping blocks are shown in Appendix E.

7.8 Constant Head Permeability Test Result

The results of the constant head permeability test results as shown below in Table 9.

Table 9: Constant Head Permeability Test Results

Bore	Depth (m)	Material Type	Ksat m/day
2	0.5	Clay	0.06
5	0.5	Clay	0.02
7	0.5	Clay	0.28
11	0.5	Clay	0.09
13	0.5	Clay	0.02
16	0.5	Clay	0.01

Notes (i) Ksat – Coefficient of Permeability.
(ii) Above depth recorded from site level at the time of the investigation.

It should be noted that absorption into the soil was slow and would generally be Category 6 *'Heavy clay'* in accordance with AS/NZS1547-2012 (Ref 10). Further laboratory testing such as dispersivity, chemical testing etc. may be required to assess soil parameters before final effluent disposal system design is adopted.

8. Limitations

Douglas Partners Pty Ltd (DP) has prepared this preliminary report for the proposed rural land sharing communities at Kyogle Road, Kunghur in accordance with DP's proposal GLD180344 dated 14 November 2018. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of NCV Enterprises Pty Ltd, or their consultants, as authorised, for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage.

In preparing this report, DP has necessarily relied upon information provided by the client and/or their agents.

The scope for work for this report did not include the assessment of surface or subsurface materials or groundwater for contaminants, within or adjacent to the site. Given the evidence of filling of unknown origin as noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during constructions and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life.

This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current

scope of works, if so requested, and provided that suitable additional information is made available to DP.

Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

9. References

1. Australian Standard AS 2870–2011 “Residential Slabs and Footings”, Standards Australia.
2. Fox E, ‘A Climate-Based Design Depth of Moisture Change Map of Queensland and the Use of Such Maps to Classify Sites Under AS 2870-1996’ Australian Geomechanics, Vol 35, No 4, December 2000.
3. Australian Standard AS 3798–2007 “Guidelines on Earthworks for Commercial and Residential Developments”, Standards Australia.
4. CSIRO Guidelines (BTF 18) “Foundation Maintenance and Footing Performance: A Home-owner’s Guide”, 2003.
5. Australian Standard AS 2159 “Piling – Design and Installation”, Standards Australia.
6. ‘Practice Note Guidelines for Landslip Risk Management’, AGS Landslide Task Force, Landslide Practice Note Working Group, Australian Geomechanics, Vol 42, No. 1, March 2007.
7. ‘Geomechanical Stability Assessment Guidelines, 2007 ‘A Method of Zoning Landslip, Hazard’ (Australian Geomechanics Society Volume 36, No. 3, September 2001).
8. ‘Australian Geoguides for Slope Management and Maintenance Working Group’, ‘AGS Landslip Task Force, Landslope Practice Note Working Group’, Australian Geomechanics Vol 41, No. 1 March 2007.
9. State Planning Policy 1103 ‘Mitigating the Adverse Impacts of Flood, Bushfire and Landslip’.
10. Australian Standard ‘AS/NZS 1547-2012 ‘Onsite Domestic Waste Water Management’, Standards Australia.

Douglas Partners Pty Ltd

Appendix A

About This Report
Sampling Methods
Soil and Rock Descriptions
Symbols and Abbreviations

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Soil Descriptions

Douglas Partners

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 -5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $Is_{(50)}$ MPa	Approx Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200
Extremely high	EH	>10	>200

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable
Moderately weathered	MW	Staining and discolouration of rock substance has taken place
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock
Fresh stained	Fs	Rock substance unaffected by weathering but staining visible along defects
Fresh	Fr	No signs of decomposition or staining

Degree of Fracturing

The following classification applies to the spacing of natural fractures in diamond drill cores. It includes bedding plane partings, joints and other defects, but excludes drilling breaks.

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and loner sections
Unbroken	Core lengths mostly > 1000 mm

Rock Descriptions

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq \text{100 mm long}}{\text{total drilled length of section being assessed}}$$

where 'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling or handling (i.e. drilling breaks) then the broken pieces are fitted back together and are not included in the calculation of RQD.

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	< 6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	> 2 m

Symbols & Abbreviations

Douglas Partners

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

Asphalt

Road base

Concrete

Filling

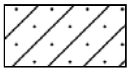
Soils

Topsoil

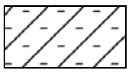
Peat

Clay

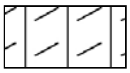
Silty clay

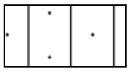

Sandy clay

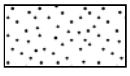
Gravelly clay

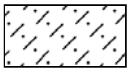

Shaly clay

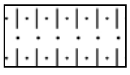
Silt


Clayey silt


Sandy silt

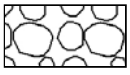

Sand

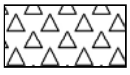

Clayey sand


Silty sand

Gravel

Sandy gravel


Cobbles, boulders

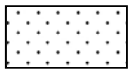

Talus

Sedimentary Rocks

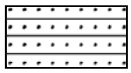
Boulder conglomerate

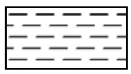
Conglomerate

Conglomeratic sandstone

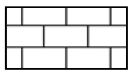

Sandstone

Siltstone


Laminite

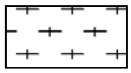

Mudstone, claystone, shale

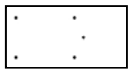
Coal


Limestone

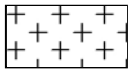
Metamorphic Rocks

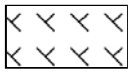
Slate, phyllite, schist

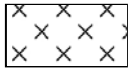

Gneiss

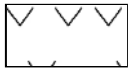

Quartzite

Igneous Rocks


Granite


Dolerite, basalt, andesite

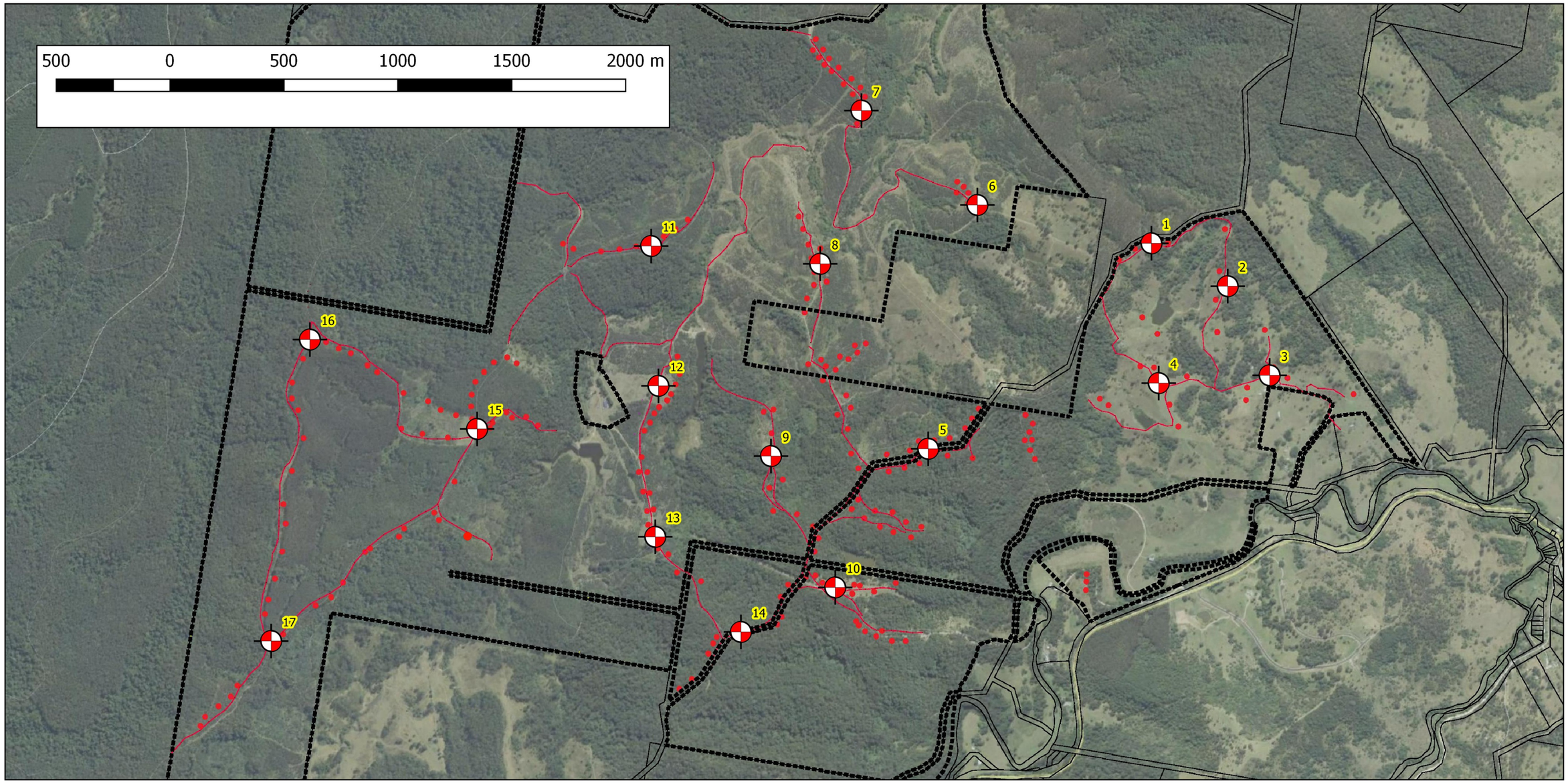

Dacite, epidote


Tuff, breccia

Porphyry

Appendix B

Drawing 1 – Test Location Plan



Legend:

- Possible Dwelling Location
- Bore Number and Location

Note:

1. Test Locations are approximate only and are shown with reference to existing site features.
2. Image adopted from client provided drawing.

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	NCV Enterprises Pty Ltd		
OFFICE:	Gold Coast	DRAWN BY:	MH
SCALE:	1:18000 @ A3	DATE:	March 2019

TITLE: **Test Location Plan**
Proposed Eco Village Cabins
Kyogle Road, Kunghur

N

PROJECT No:	90579.00
DRAWING No:	1
REVISION:	0

Appendix C

Borehole Logs (Bores 1 to 17)

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 181.4 mAHD
EASTING: 522971
NORTHING: 6851987
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 90579.00
DATE: 16/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
181	0.0	SILTY SAND (SM) - medium dense grey silty sand, fine sand with some clay. Root zone to 0.1m		D	0.1				
					0.4				
	0.5	SILTY CLAY (CI) - stiff pale grey with orange silty clay with traces of fine sand		D					
	1.0				0.8				
	1.1	- hard							
180		- completely weathered siltstone. Encountered as hard sandy/silty clay.							
	1.9	SILTSTONE - very low strength grey with orange siltstone							
179	2.4	Bore discontinued at 2.4m TC Bit refusal. Limit of Investigation							
178									
177									

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20; 1, 2, 3, 4

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 148.8 mAHD
EASTING: 523306
NORTHING: 6851799
DIP/AZIMUTH: 90°/--

BORE No: 2
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
148	0.3	SILTY SAND (SM) - medium dense to dense brown grey silty sand, fine sand, traces of fine to medium gravels, dry							5 10 15 20
		- pale brown with some clay		D	0.3 0.4				
	0.5	SILTY CLAY (CI) - stiff to very stiff pale brown with orange silty clay with some fine sand, moist (grading to very low strength siltstone)		D	0.6 0.8				
	0.9	SILTSTONE - very low strength grey with orange siltstone							
147	1.0	Bore discontinued at 1.0m TC Bit refusal. Limit of Investigation							
146									
145									
144									

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 116.4 mAHD
EASTING: 523490
NORTHING: 6851408
DIP/AZIMUTH: 90°/--

BORE No: 3
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
116	0.4	SILTY SAND (SM) - medium dense to dense grey silty sand, fine to medium sand with some fine to medium gravels and clay, moist. Root zone to 0.1m							
		SILTY CLAY (CI-CH) - stiff orange with grey silty clay with some fine to medium sand, moist		D	0.4 0.6				
	0.8	- grey with orange		D	0.8 1.1				
115	1								
	1.8	- completely weathered siltstone. Encountered as hard sandy/silty clay.							
114	2			D	2.5 2.8				
	3.0	Bore discontinued at 3.0m Limit of Investigation							
113	3								
112	4								

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

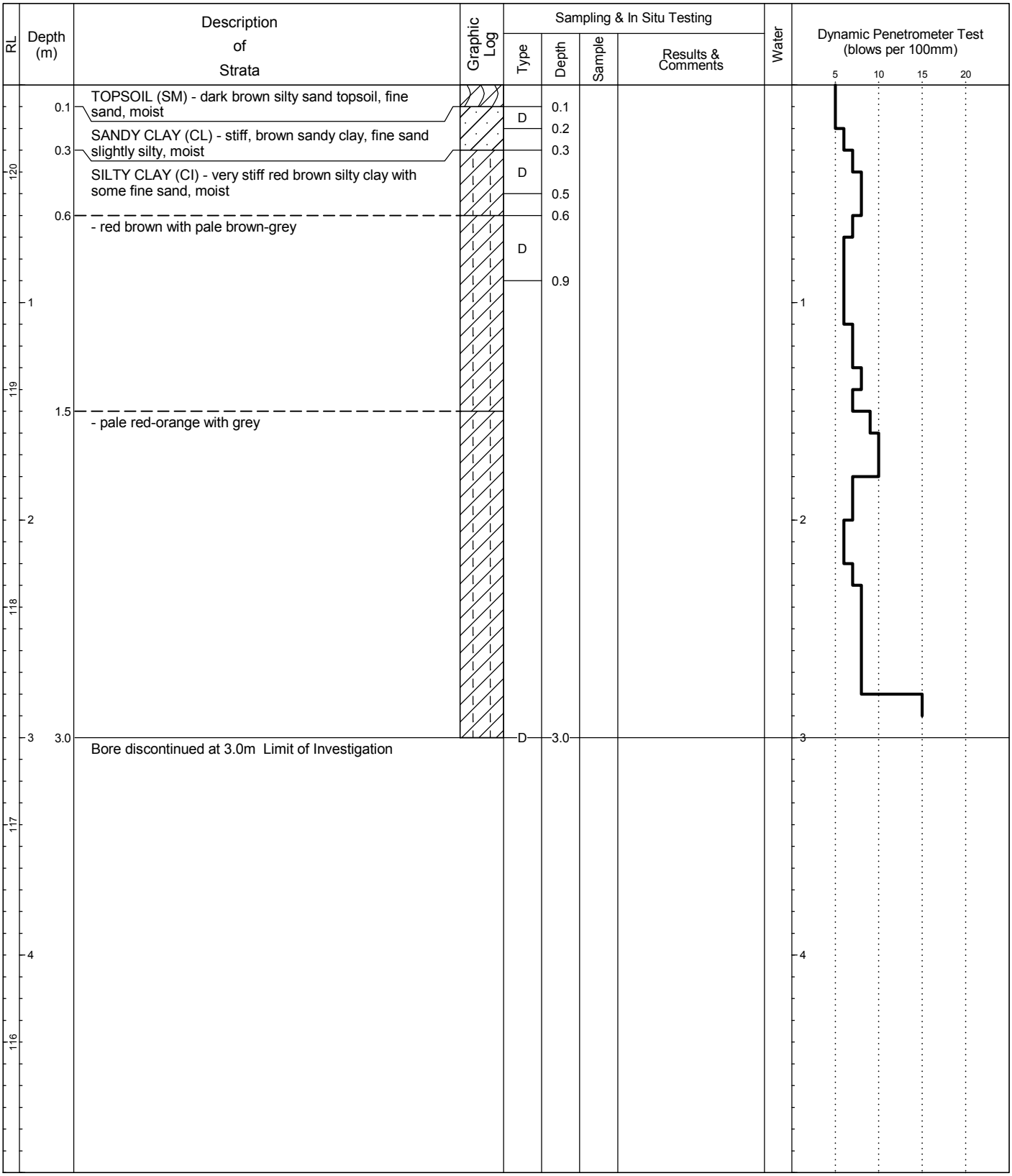
Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 120.4 mAHD
EASTING: 523003
NORTHING: 6851374
DIP/AZIMUTH: 90°/--

BORE No: 4
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1



RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 189.4 mAHD
EASTING: 521991
NORTHING: 6851086
DIP/AZIMUTH: 90°/--

BORE No: 5
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
189	0.1	CLAYEY SAND (SC) - medium dense grey brown clayey sand, fine sand, moist			0.1				
	0.3	SANDY CLAY (CL) - stiff brown with red sandy clay, fine sand with some silt, moist		D	0.3				
		SILTY CLAY (CI) - stff red with pale brown silty clay, slightly fine sand, moist		D	0.6				
	0.8	- very stiff							
188	1.3	- hard pale orange/brown		D	1.2				
					1.4				
	1.8	- orange with pale grey							
187	2.7	- completely weathered siltstone. Encountered as hard sandy/silty clay.							
	3.0	Bore discontinued at 3.0m Limit of Investigation							
186									
185									

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 166.4 mAHD
EASTING: 522207
NORTHING: 6852155
DIP/AZIMUTH: 90°/--

BORE No: 6
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
166	0.2	SILTY SAND (SM) - medium dense grey silty sand, fine sand, moist							
		SILTY CLAY (CI) - stiff to very stiff pale brown with grey silty clay, slightly fine sand, moist		D	0.3				
					0.6				
	0.8	GRAVELLY CLAY (CL) - very stiff pale brown orange gravelly clay, with some fine sand and silt, fine to medium gravels, moist. Tending to weathered rock.							
	1.0	- hard		D	1.0				
	1.2	- completely weathered siltstone. Encountered as hard silty/sandy clay			1.1				
165	1.7								
	1.8	SILTSTONE - very low strength grey with orange siltstone							
		Bore discontinued at 1.8m TC Bit refusal. Limit of Investigation							
164									
163									
162									

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 152.5 mAHD
EASTING: 521698
NORTHING: 6852569
DIP/AZIMUTH: 90°/--

BORE No: 7
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
152	0.1	CLAYEY SAND (SC) - medium dense grey brown clayey sand, fine sand, moist							
	0.3	SANDY CLAY (CL) - stiff brown with red sandy clay, fine sand with some silt, moist							
		SILTY CLAY (CI-CH) - stiff red with pale brown silty clay, trace fine sand, moist		D	0.3				
					0.6				
	0.9	- very stiff, red with fine grey and orange							
151	1.4	- hard, pale grey with orange and red. Tending to weathered rock.							
	2.1	- red brown							
150	3.0	Bore discontinued at 3.0m Limit of Investigation							
149									
148									

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20; 1, 2, 3, 4

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 149.0 mAHD
EASTING: 521517
NORTHING: 6851897
DIP/AZIMUTH: 90°/--

BORE No: 8
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
149	0.1	SILTY SAND (SM) - medium dense grey silty sand, fine sand, moist							
	0.3	SANDY CLAY (CL) - stiff, grey with red sandy clay, fine sand slightly silty, moist							
		SILTY CLAY (CI) - very stiff red with grey and orange silty clay, trace fine sand, moist		D	0.3				
					0.6				
	0.8	- orange with red and grey							
148	1								1
	1.5	- hard grey with red and orange. Tending to weathered rock		D	1.5				
					2.0				
147	2								2
	2.7	- grey with pale grey		D	2.7				
					2.8				
146	3								3
	3.0	Bore discontinued at 3.0m Limit of Investigation							
145	4								4

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 183.4 mAHD
EASTING: 521301
NORTHING: 6851054
DIP/AZIMUTH: 90°/--

BORE No: 9
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
183	0.2	CLAYEY SAND (SC) - medium dense grey clayey sand, fine sand with silt, moist							
	0.5	SILTY CLAY (CL) - stiff brown with red silty clay with some fine sand, moist							
		SILTY CLAY (CI-CH) - stiff red with grey silty clay, moist		D	0.5 0.6				
	0.9	- very stiff pale grey with orange							
182	1.2	- hard							
	1.5	- completely weathered siltstone. Encountered as hard silty/sandy clay							
181									
	3.0	Bore discontinued at 3.0m Limit of Investigation							
180									
179									

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20; 1, 2, 3, 4

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 190.7 mAHD
EASTING: 521583
NORTHING: 6850478
DIP/AZIMUTH: 90°/--

BORE No: 10
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
190	0.1	CLAYEY SAND (SC) - medium dense grey brown clayey sand, fine sand, moist							
	0.3	SANDY CLAY (CL) - stiff grey with orange sandy clay, fine sand, slightly silty, moist							
		SILTY CLAY (CI-CH) - stiff red with pale brown silty clay, moist (tree roots)		D	0.3				
					0.6				
	0.8	- red orange pale grey							
189	1.3	- hard orange with pale grey. Tending to weathered rock							
	1.6	- pale grey with orange and red							
188									
	3.0	Bore discontinued at 3.0m Limit of Investigation							
187									
186									

5 10 15 20

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 169.8 mAHD
EASTING: 520775
NORTHING: 6851975
DIP/AZIMUTH: 90°/--

BORE No: 11
PROJECT No: 90579.00
DATE: 14/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
169	0.1	SILTY SAND (SM) - medium dense brown silty sand, fine sand with some clay, moist			0.1				
	0.3	SANDY CLAY (CL) - stiff, brown sandy clay, fine sand, slightly silty, moist		D	0.3				
		- red brown		D					
	0.5	- red with pale brown			0.6				
	0.7	- red with pale grey							
	1.0	- pale grey with red							
168	1.9	- very stiff							
167	3.0	Bore discontinued at 3.0m Limit of Investigation							
166									
165									

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 158.5 mAHD
EASTING: 520807
NORTHING: 6851362
DIP/AZIMUTH: 90°/--

BORE No: 12
PROJECT No: 90579.00
DATE: 16/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
158	0.0	SILTY SAND (SM) - medium dense dark brown silty sand with some clay, fine sand, moist							
	0.3	SANDY CLAY (CI-CL) - stiff, brown with orange sandy clay, fine sand, slightly silty, moist		D	0.3				
	0.6	SILTY CLAY (CI) - stiff pale brown with red pale grey silty clay, moist		D	0.6				
157	0.9	- pale grey with red and orange		D	0.9 1.2 1.3				
	1.6	- hard. Tending to weathered rock							
156	2.2	- orange with grey							
155	3.0	Bore discontinued at 3.0m Limit of Investigation							
154									

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 169.9 mAHD
EASTING: 520793
NORTHING: 6850700
DIP/AZIMUTH: 90°/--

BORE No: 13
PROJECT No: 90579.00
DATE: 16/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
169	0.1	SILTY SAND (SM) - medium dense brown silty sand with some fine sand with some fine to coarse gravels and clay, moist							
	0.3	SILTY CLAY (CI) - stiff brown with red silty clay with some fine sand, moist		D	0.2				
		SILTY CLAY (CI-CH) - stiff red with grey silty clay, with traces of fine sand, moist			0.6				
	0.8	-very stiff pale grey with red							
168	1.3	- hard grey with orange. Tending to weathered rock							
167	3.0	Bore discontinued at 3.0m Limit of Investigation							
166									
165									

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 203.7 mAHD
EASTING: 521169
NORTHING: 6850283
DIP/AZIMUTH: 90°/--

BORE No: 14
PROJECT No: 90579.00
DATE: 16/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
203	0.0	SANDY CLAY (CL) - stiff, pale brown sandy clay, fine sand, slightly silty, moist. Tree roots to 0.7m.		D	0.1				
					0.3				
	0.6	- hard							
	0.9	- completely weathered siltstone. Encountered as hard silty/sandy clay							
202	2.2	- grey with pale brown							
201	3.0	Bore discontinued at 3.0m Limit of Investigation							
200									
199									

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 166.9 mAHD
EASTING: 520011
NORTHING: 6851173
DIP/AZIMUTH: 90°/--

BORE No: 15
PROJECT No: 90579.00
DATE: 16/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
166	0.0	SANDY CLAY (CH) - stiff brown sandy clay, fine sand with some silt, moist		D	0.1				
	0.3	- brown with red		D	0.3				
	0.6	- red with pale grey		D	0.6				
	1				0.9				1
	1.2	- pale grey with red							
	1.7	- pale grey and grey							
165	2	2.0 - hard. Tending to weathered rock							2
	2.8	SILTY CLAY (CI-CH) - hard pale grey with orange silty clay, moist. Tending to weathered rock							
164	3	3.0 Bore discontinued at 3.0m Limit of Investigation							3
163	4								4
162									

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 214 mAHD
EASTING: 519277
NORTHING: 6851565
DIP/AZIMUTH: 90°/--

BORE No: 16
PROJECT No: 90579.00
DATE: 16/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
214	0.1	SILTY SAND (SM) - medium dense grey silty sand, fine sand with some clay, moist		D	0.1				
		SILTY CLAY (CI-CH) - stiff red silty clay with traces of sand, moist			0.3				
	0.6	- red with dark grey							
213	1								1
	1.2	- very stiff pale grey with red							
	1.6	- hard, pale grey with orange. Tending to weathered rock							
212	2								2
211	3								3
	3.0	Bore discontinued at 3.0m Limit of Investigation							
210	4								4

Dynamic Penetrometer Test (blows per 100mm): 5, 10, 15, 20

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NCV Enterprises Pty Ltd
PROJECT: Proposed Rural Land Sharing Communities
LOCATION: Kyogle Road, Kunghur

SURFACE LEVEL: 227 mAHD
EASTING: 519107
NORTHING: 6850243
DIP/AZIMUTH: 90°/--

BORE No: 17
PROJECT No: 90579.00
DATE: 16/1/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per 100mm)
227	0.1	SILTY SAND (SM) - medium dense grey silty sand, fine sand with some clay, moist							
		SILTY CLAY (CI-CH) - stiff, red silty clay traces of fine sand, moist			0.4				
	0.5	SILTY CLAY (CI) - stiff red with pale grey silty clay, moist		D					
	0.7	- pale grey with red			0.8				
226	1 1.0	- very stiff, pale grey with orange							1
225	2								2
	2.3	- hard							
	2.8	- completely weathered sandstone. Encountered as hard silty/sandy clay							
224	3 3.0	Bore discontinued at 3.0m Limit of Investigation							3
223	4								4

RIG: Christie Soil Rig **DRILLER:** Geoserve **LOGGED:** BM/MH **CASING:** N/A

TYPE OF BORING: Auger

WATER OBSERVATIONS: No groundwater observed during the investigation

REMARKS: Surface level interpolated from Nearmap imagery dated 1 January 2005.

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

Appendix D

CSIRO Publication

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO

BTF 18 replaces Information Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction
There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion
All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation
This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil
All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure
This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- **Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.**
- **Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.**

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

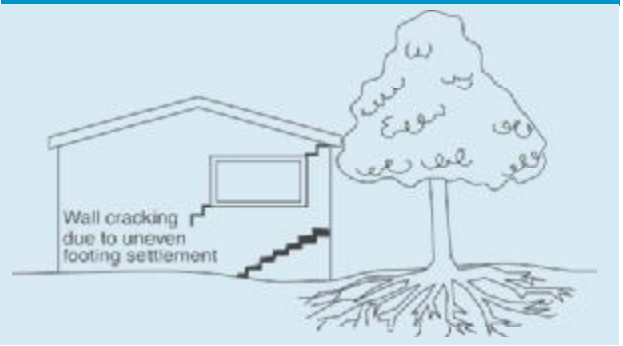
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

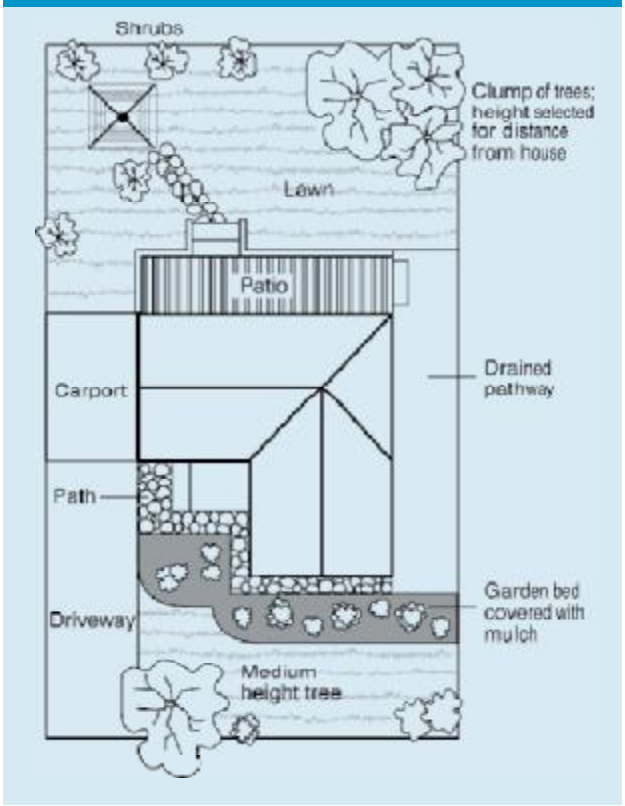
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

Distributed by

CSIRO PUBLISHING PO Box 1139, Collingwood 3066, Australia

Freecall 1800 645 051 Tel (03) 9662 7666 Fax (03) 9662 7555 www.publish.csiro.au

Email: publishing.sales@csiro.au

© CSIRO 2003. Unauthorised copying of this Building Technology file is prohibited

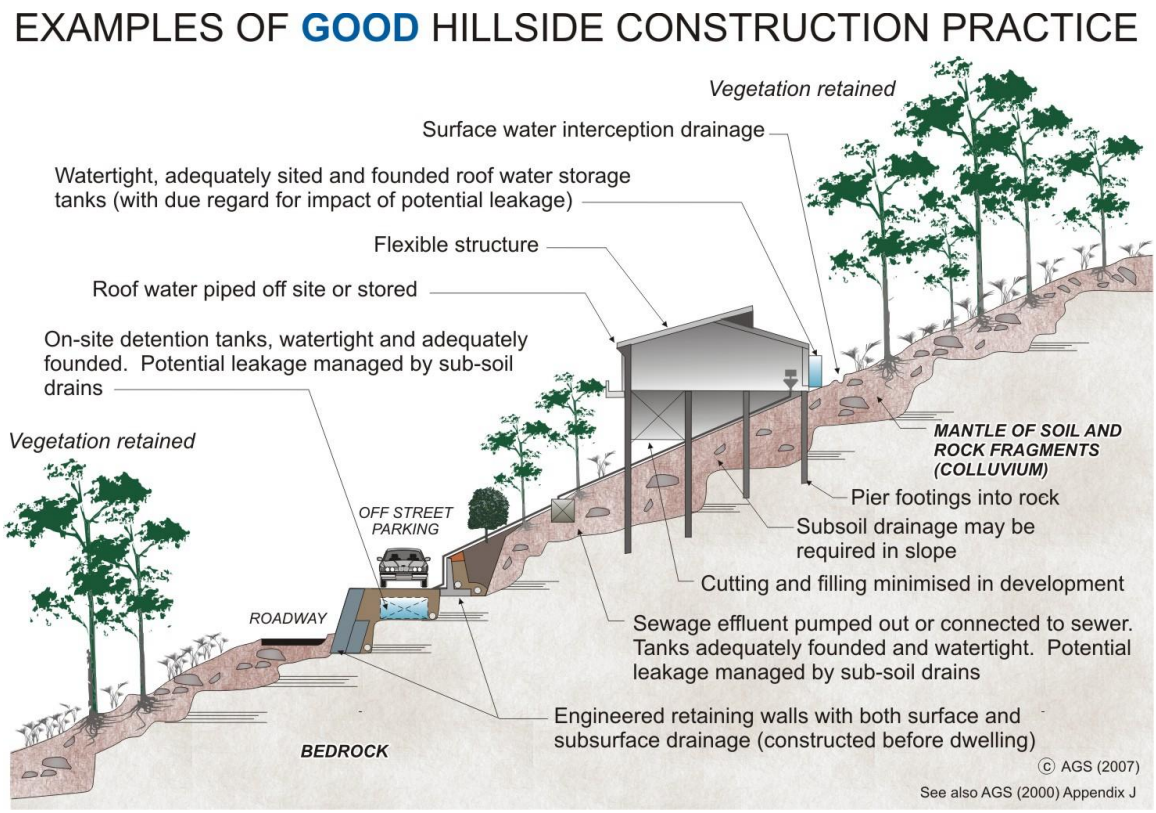
Appendix E

Australian Geoguides LR8

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.


EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE
Vegetation retained
Surface water interception drainage
Watertight, adequately sited and founded roof water storage tanks (with due regard for impact of potential leakage)
Flexible structure
Roof water piped off site or stored
On-site detention tanks, watertight and adequately founded. Potential leakage managed by sub-soil drains
Vegetation retained
MANTLE OF SOIL AND ROCK FRAGMENTS (COLLUVIUM)
Pier footings into rock
OFF STREET PARKING
Subsoil drainage may be required in slope
Cutting and filling minimised in development
ROADWAY
Sewage effluent pumped out or connected to sewer. Tanks adequately founded and watertight. Potential leakage managed by sub-soil drains
Engineered retaining walls with both surface and subsurface drainage (constructed before dwelling)
BEDROCK
© AGS (2007)
See also AGS (2000) Appendix J

WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

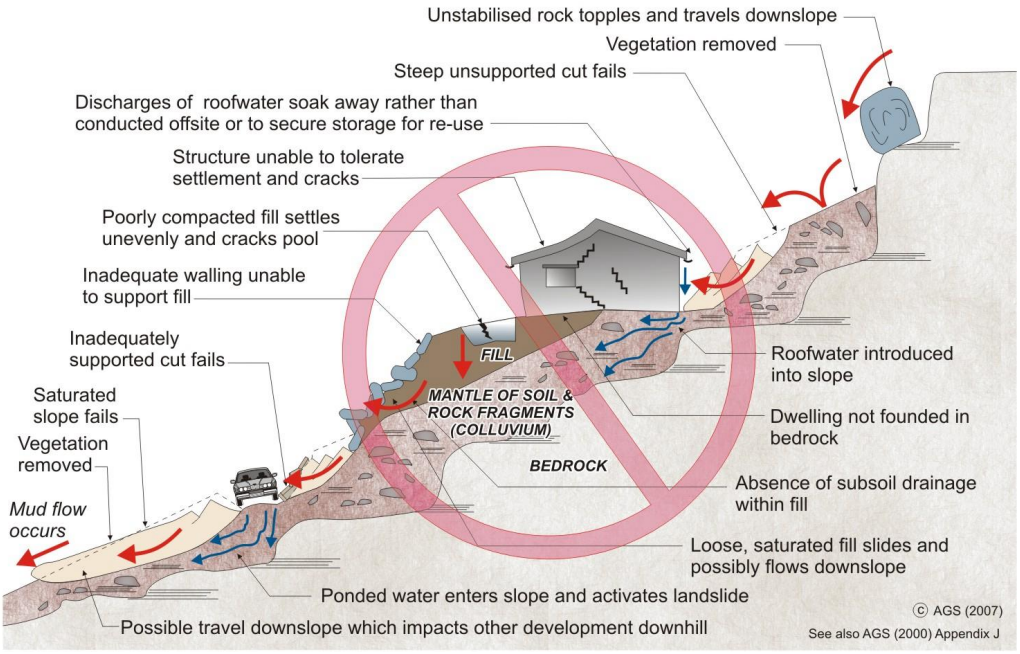
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF **POOR** HILLSIDE CONSTRUCTION PRACTICE


Unstabilised rock topples and travels downslope
Vegetation removed
Steep unsupported cut fails
Discharges of roofwater soak away rather than conducted offsite or to secure storage for re-use
Structure unable to tolerate settlement and cracks
Poorly compacted fill settles unevenly and cracks pool
Inadequate walling unable to support fill
Inadequately supported cut fails
Saturated slope fails
Vegetation removed
Mud flow occurs
FILL
MANTLE OF SOIL & ROCK FRAGMENTS (COLLUVIUM)
BEDROCK
Roofwater introduced into slope
Dwelling not founded in bedrock
Absence of subsoil drainage within fill
Loose, saturated fill slides and possibly flows downslope
Ponded water enters slope and activates landslide
Possible travel downslope which impacts other development downhill
© AGS (2007)
See also AGS (2000) Appendix J

WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.